Balanced Y- Connected Voltage Source

✓ Line currents equal phase Currents

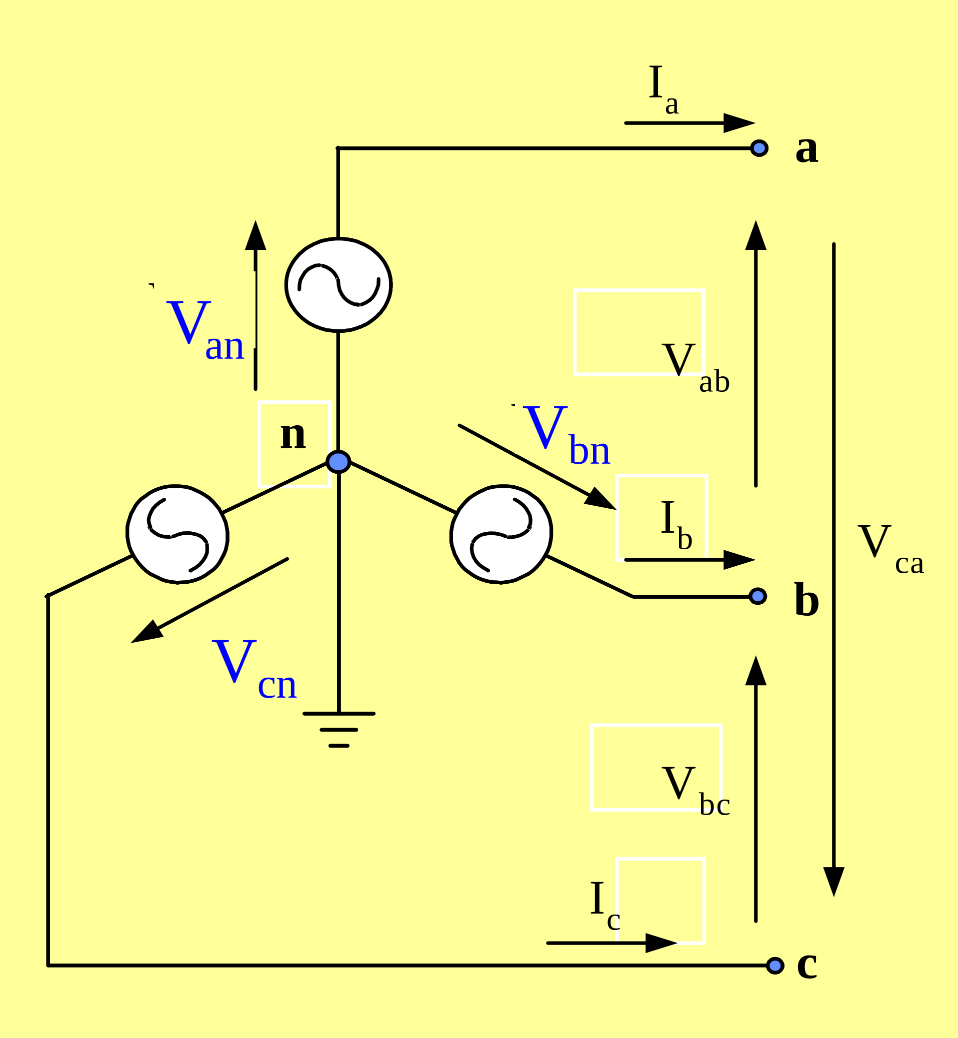
$$\boxed{I_L = I_\varphi}$$

✓Phase voltages are

(V_{an}, V_{bn}, V_{cn})

✓Line voltages are

(V_{ab}, V_{bc}, V_{ca})



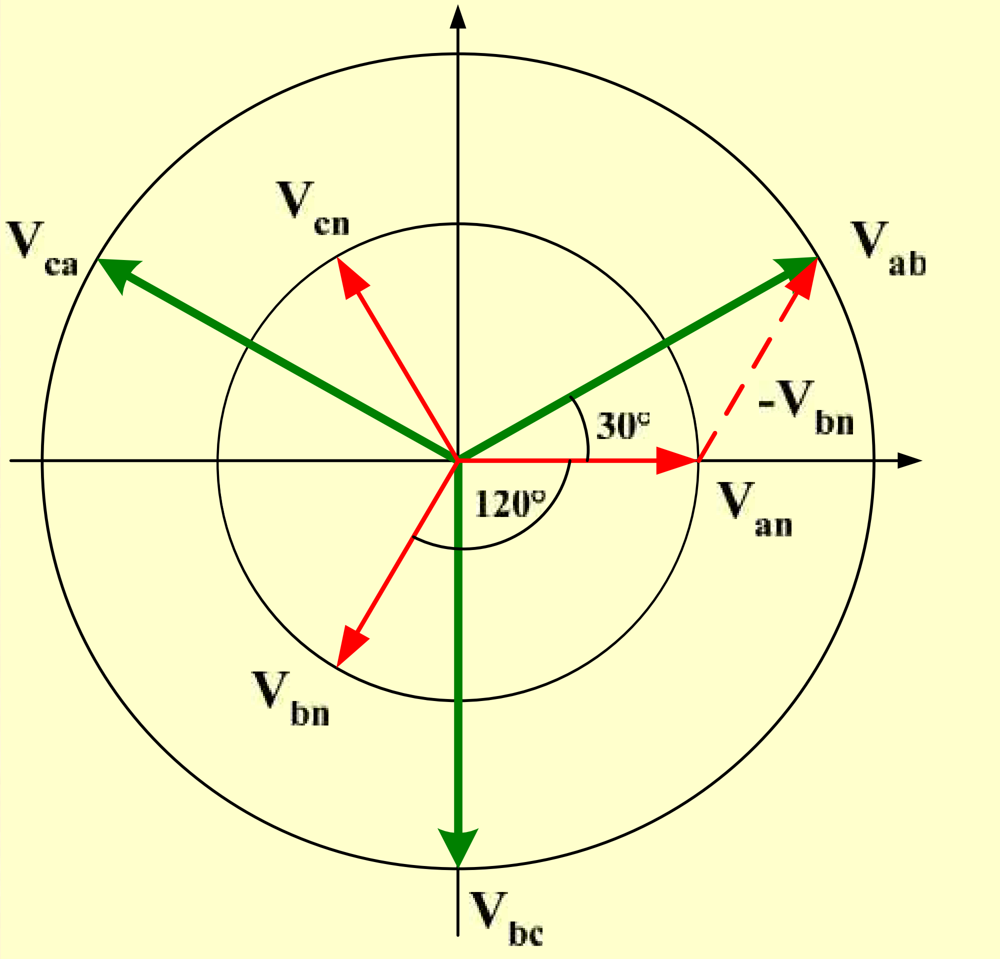
Phase Diagram of Line and Phase Voltages (+ve Sequence)

- **PHASE VOLTAGE**

$$V_{an} = V\angle 0^\circ$$
$$V_{bn} = V\angle -120^\circ$$
$$V_{cn} = V\angle +120^\circ$$

- **LINE VOLTAGE**

$$V_{ab} = V_{an} - V_{bn}$$
$$V_{bc} = V_{bn} - V_{cn}$$
$$V_{ca} = V_{cn} - V_{an}$$



Relation Between Line and Phase Voltages (+ve Sequence)

LINE VOLTAGE (V_L)

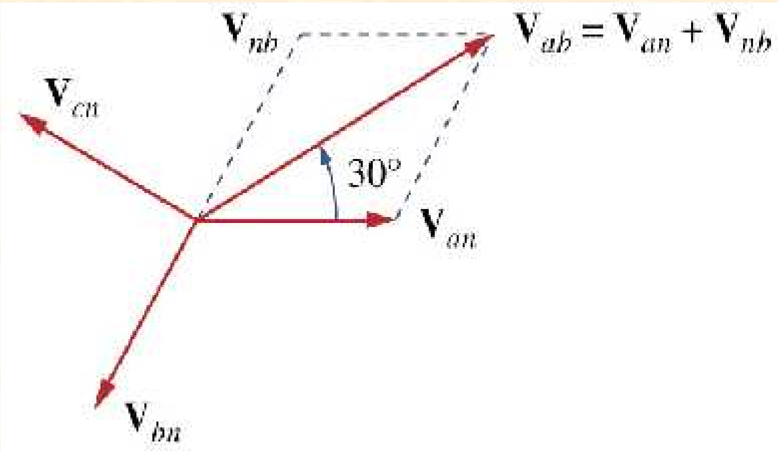
$$\left\{\begin{aligned} V_{ab} &= \sqrt{3}\,V\angle 30^\circ \\ V_{bc} &= \sqrt{3}\,V\angle -90^\circ \\ V_{ca} &= \sqrt{3}\,V\angle 150^\circ \end{aligned}\right.$$

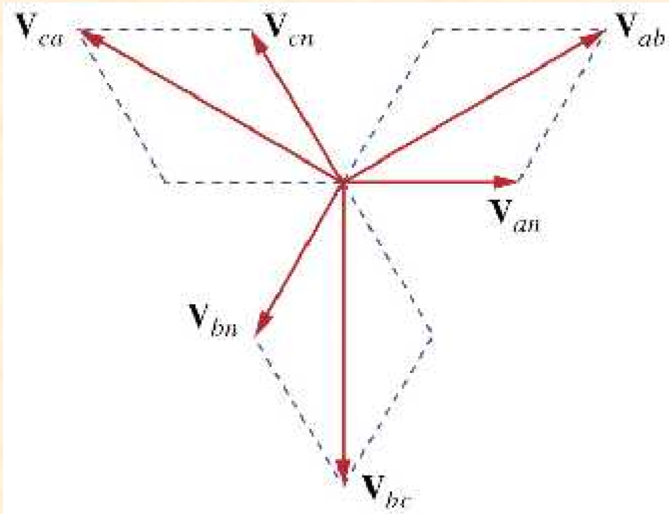
$$|V_L| = \sqrt{3}\,|V_{¤}|$$

$$\angle V_L = \angle V_{¤} + 30^\circ$$

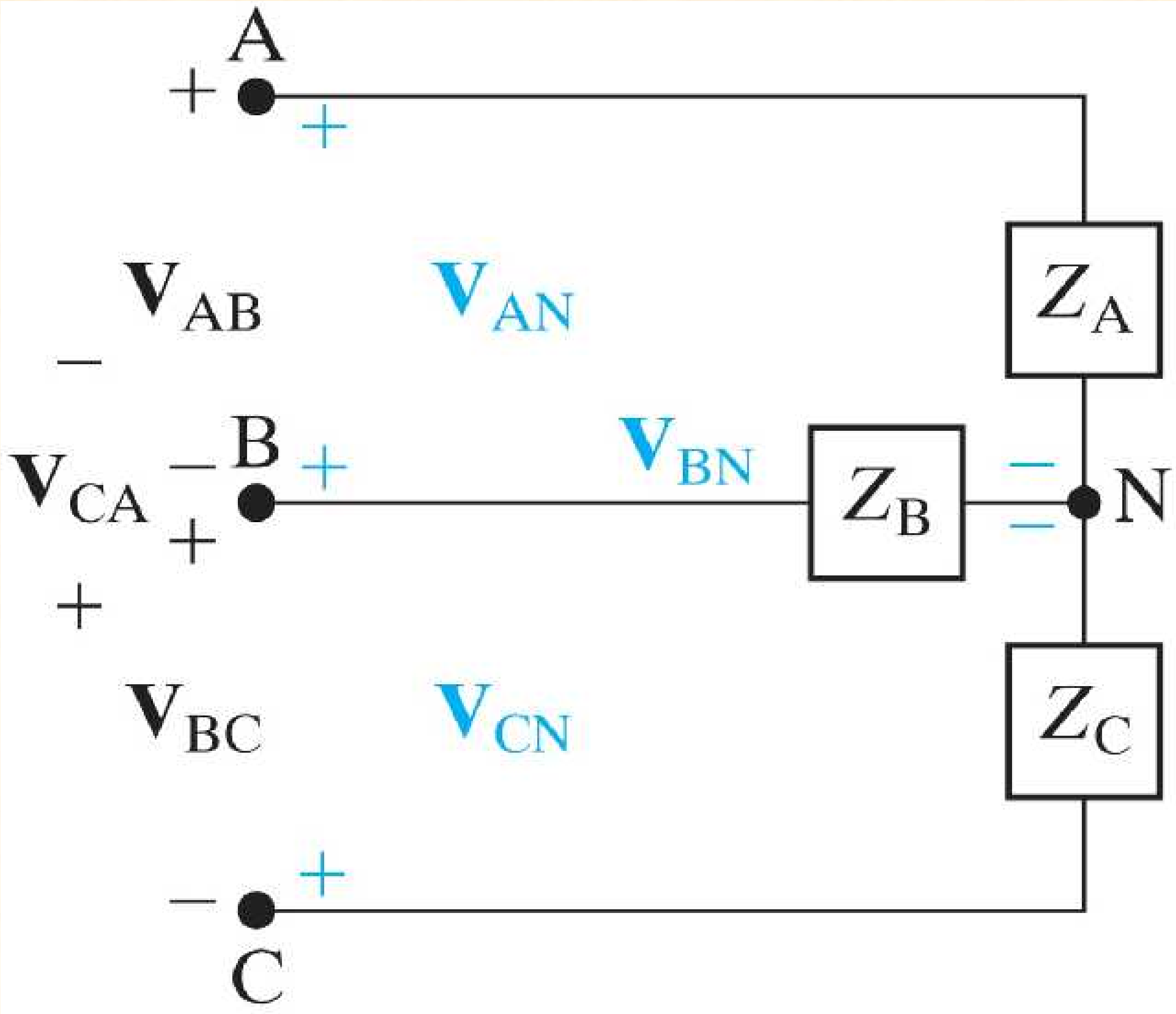
Conclusions for Balanced Y-connected Voltage Source

- **Balanced line voltages** are equal in magnitude and are out of phase with one another by **120** degrees
- Line voltages sum up to zero **(V_{ab} +V_{bc} +V_{ca} = 0)**
- The magnitude of line voltages is $\sqrt{3}$ times the magnitude of the phase voltages
- Line Voltages **lead** their corresponding phase voltages by 30 degrees (for +ve sequence)

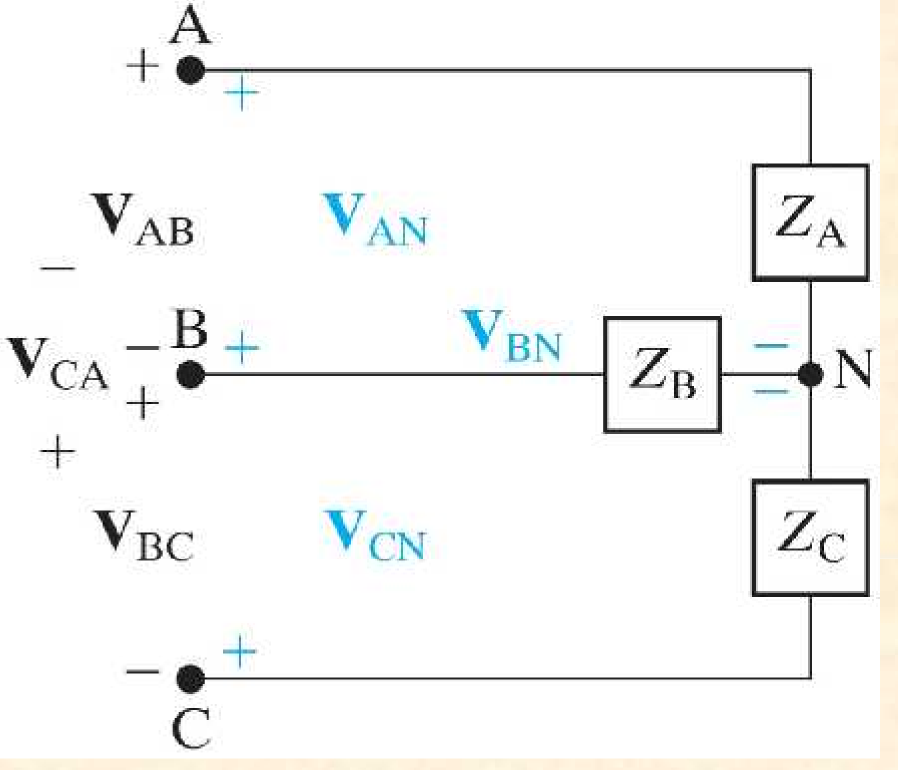




Balanced Y-connected Load



Balanced Y-connected Load



$$V_{AB} = V_{AN} - V_{BN}$$

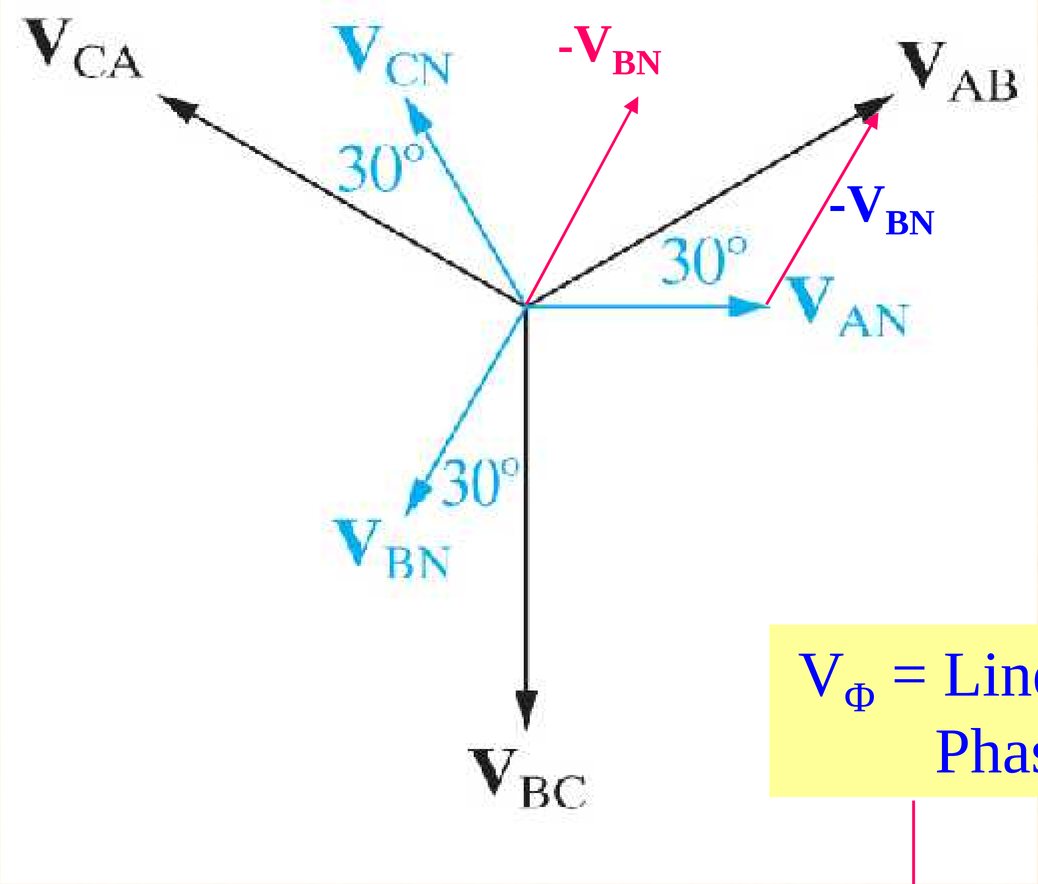
Line Voltages

$$V_{BC} = V_{BN} - V_{CN}$$

Phase Voltages

$$V_{CA} = V_{CN} - V_{AN}$$

Line and Phase Voltages for Balanced Y-connected Load



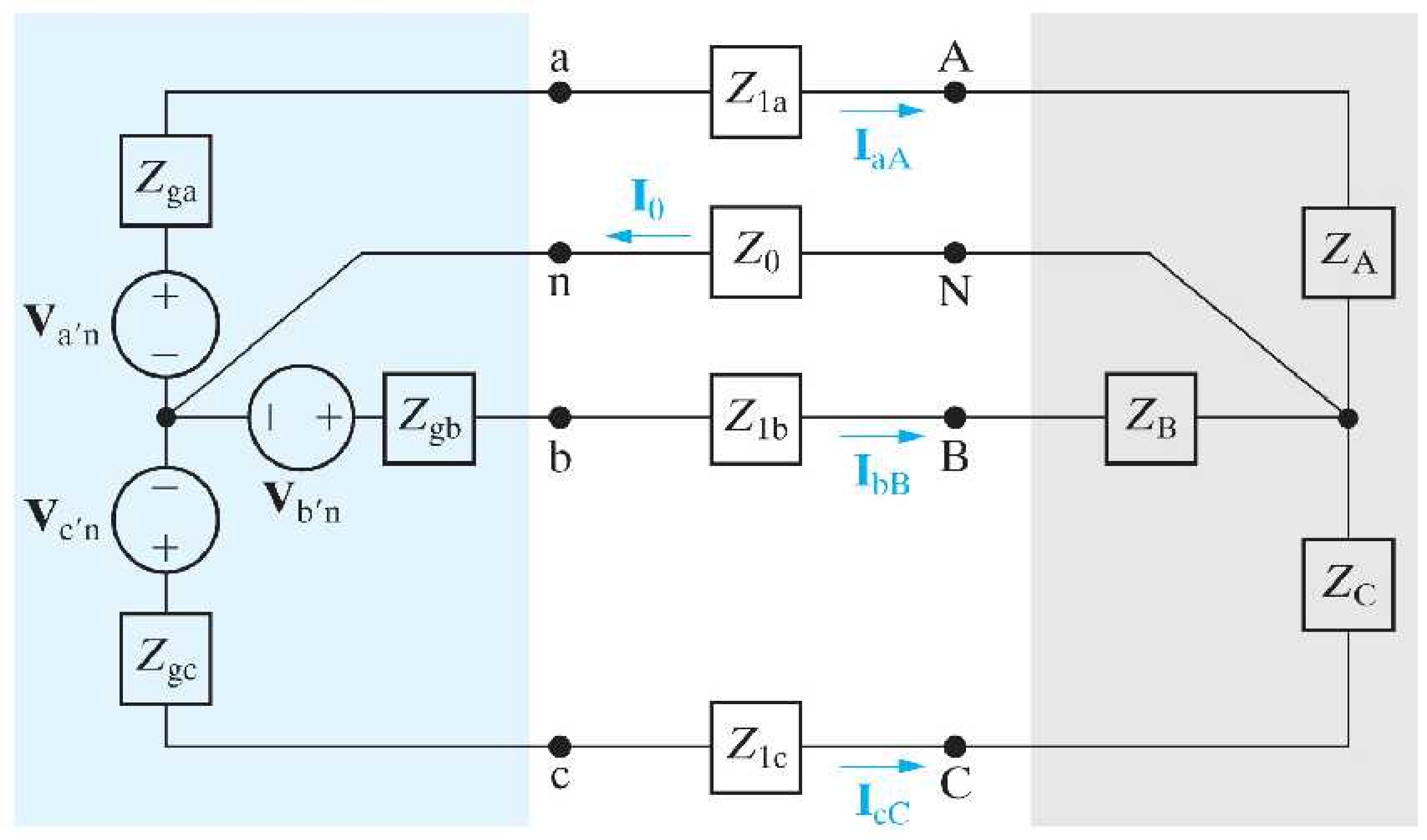
V_{Φ} = Line-to-Neutral, or Phase Voltage

$$\mathbf{V}_{AB} = \mathbf{V}_{AN} - \mathbf{V}_{BN} = \sqrt{3}\ V_{\Phi}$$

Conclusions for Balanced Y-Connected System

- The Line currents **equal** phase Currents
- The amplitude of the line-to-line voltage is equal to $\sqrt{3}$ times the amplitude of the phase voltage
- The line-to-line voltages form a balanced set of 3-phase voltages
- The set of line-to-line voltages **leads** the set of line-to-neutral (phase) voltages by 30° (for +ve sequence)
- The set of line-to-line voltages **lags** the set of line-to-neutral (phase) voltages by 30° (for -ve sequence)

Y-Y Three-Phase System (Four Wire)



Y-Y Three-Phase System (Four Wire)

- Z_g represents the internal generator impedance per phase
- Z_l represents the impedance of the line connecting the generator to the load
- $Z_{A,B,C}$ represents the load impedance per phase
- Z_o represents the impedance of the neutral conductor

Neutral Voltage for Y-Y System

➢Using source neutral as a reference, the Node-Voltage equation at node N can be written as:

$$\frac{\mathbf{V}_N}{Z_o} + \frac{\mathbf{V}_N - \mathbf{V}_{a'n}}{Z_A + Z_{1a} + Z_{ga}} + \frac{\mathbf{V}_N - \mathbf{V}_{b'n}}{Z_B + Z_{1b} + Z_{gb}} + \frac{\mathbf{V}_N - \mathbf{V}_{c'n}}{Z_C + Z_{1c} + Z_{gc}} = 0.$$

➢***For a balance three-phase system;***

✓ Three-phase voltages are balanced,

✓ **$Z_{ga} = Z_{gb} = Z_{gc}$, $Z_{la} = Z_{lb} = Z_{lc}$ and $Z_A = Z_B = Z_C$**

$$Z_\phi = Z_A + Z_{1a} + Z_{ga}$$

Neutral Voltage for Y-Y System

➤ **The neutral voltage can be given by:**

$$\mathbf{V}_N\left(\frac{1}{Z_o}+\frac{3}{Z_\phi}\right)=\frac{\mathbf{V}_{a'n}+\mathbf{V}_{b'n}+\mathbf{V}_{c'n}}{Z_\phi}.$$

❑ As the three-phase voltages are balanced (i.e. $\mathbf{V_{an}} + \mathbf{V_{bn}} + \mathbf{V_{cn}} = \mathbf{0}$), therefore the neutral voltage must be equal zero

$$\mathbf{V}_N = 0.$$